Highlights

World energy consumption is projected to increase by 60 percent from 1999 to 2020. Much of the growth in worldwide energy use is expected in the developing world in the IEO2002 reference case forecast.

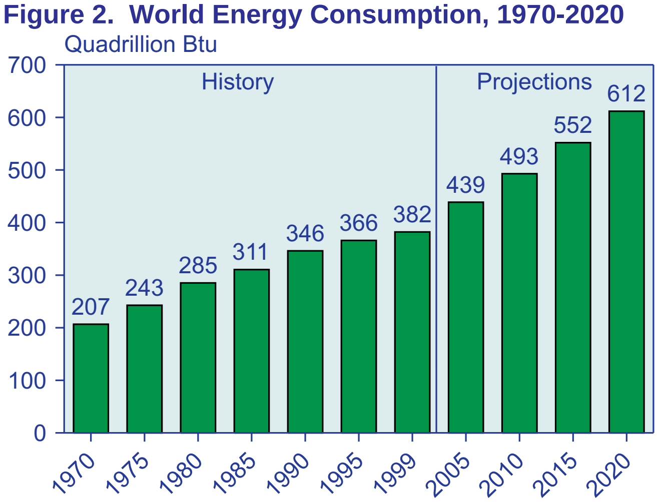
In the reference case projections for the *International Energy Outlook 2002* (*IEO2002*), world energy consumption is projected to increase by 60 percent over a 21-year forecast horizon, from 1999 to 2020. Worldwide energy use grows from 382 quadrillion British thermal units (Btu) in 1999 to 612 quadrillion Btu in 2020 (Figure 2). Energy markets were influenced by a host of developments in 2001, including high world oil prices that persisted from 2000 into the first part of 2001 and then weakened substantially in the third quarter of the year; a global economic slowdown led by a mild recession in the United States; and the aftermath of the terrorist attacks on the United States on September 11, 2001.

Despite the events of the past year, much of the growth in worldwide energy use is still expected in the developing world, as it has been in past editions of this outlook (Figure 3). In particular, energy demand in developing Asia and Central and South America is projected to more than double between 1999 and 2020. Both of these regions are expected to sustain energy demand growth of about 4 percent annually throughout the forecast, accounting for about half of the total projected increment in world energy consumption and 83 percent of the increment for the developing world alone.

High world oil prices carried into 2001 from the previous year, and for the first half of the year they remained within—and, during day trading, occasionally spiked above—the $22 to $28 per barrel price band that the Organization of Petroleum Exporting Countries (OPEC) has defined as its preferred range. Although prices spiked initially after the September 11 terrorist attacks launched on the United States, oil demand weakened substantially in the weeks and months that followed the attacks, and OPEC found it difficult to hold prices much above the $22 per barrel mark. Even after three production quota cuts amounting to 3.5 million barrels per day were made in 2001, prices did not strengthen. At the end of 2001, OPEC entered into a protracted negotiation with key non-OPEC producers aimed at reducing oil exports enough to shore up the world market price. OPEC members (excluding Iraq) agreed to cut 1.5 million barrels of production, and non-OPEC producers Angola, Norway, Mexico, Oman, and Russia agreed to take a combined 462,500 barrels per day out of the export market beginning in January 2002.

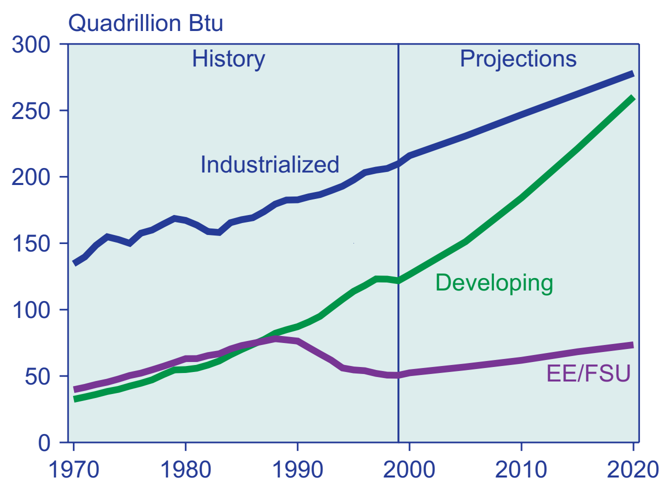
The U.S. refiner acquisition cost of imported crude oil fell from $27.72 per barrel in 2000 to an estimated $22.05 per barrel in 2001 (nominal dollars). The *IEO2002*

Figure 2. World Energy Consumption, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 3. World Energy Consumption by Region, 1970-2020



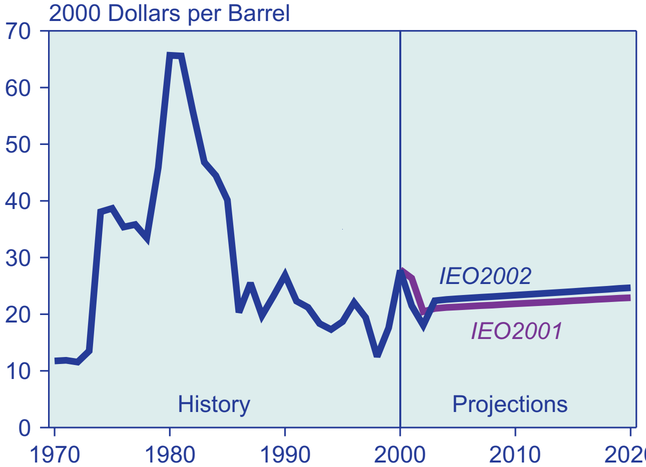
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

reference case expects world oil prices to moderate in 2002 and return to the price trajectory anticipated in last year's outlook for the mid-term. World oil prices are expected to reach $25 per barrel in 2000 dollars ($42 per barrel in nominal dollars) at the end of the projection period. This year's projection for world oil prices is slightly higher than last year's projection (Figure 4), reflecting the successes OPEC had in managing oil production cutbacks to raise oil prices in 2000, along with a more optimistic mid-term outlook for demand in the world's developing countries.

Outlook for World Energy Demand

Much of the industrialized world experienced economic slowdown in 2001, led by what is estimated to have been a recession in the United States since March 2001. The lowered economic activity in the industrialized world will have short-term impacts on the rest of the world as demand for products and services from developing countries slows in response. Lowered demand for computer equipment has already nudged high-tech exporters South Korea and Taiwan into recession. The mid-term forecast assumes that the recession will not be protracted in the United States, and that gross domestic product (GDP) growth and energy demand growth will rebound and will largely resume the trend projected in last year's outlook. The *IEO2002* reference case expects that energy consumption in the industrialized world will grow by 1.3 percent per year between 1999 and 2020, slightly higher than the 1.2 percent per year projected in last year's report.

Figure 4. Comparison of 2001 and 2002 World Oil Price Projections



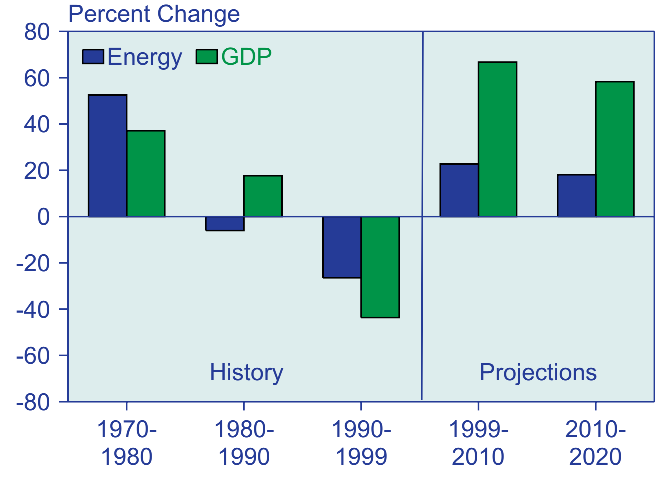
Sources: **History:** Energy Information Administration (EIA), *Annual Energy Review 2000*, DOE/EIA-0384(2000) (Washington, DC, July 2001). ***IEO2001:*** EIA, *International Energy Outlook 2001*, DOE/EIA-0484(2001) (Washington, DC, March 2001). ***IEO2002:*** 1999-2002—EIA, *Short-Term Energy Outlook*, on-line version (February 7, 2002), web site www.eia.doe.gov/emeu/steo/pub/contents.html. 2003-2020—EIA, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, December 2001).

One of the few bright spots among the world's regional economies in 2001 was the former Soviet Union (FSU), where GDP registered a second year of positive growth for every nation in the region. High oil prices and a devalued ruble helped Russia—the region's largest economy—post strong economic gains by boosting performance in the country's industrial sector. As the ruble regained value in 2001, the manufacturing sector slowed somewhat (as imported goods once again could compete with domestic goods), but high world oil prices in the first three quarters of the year helped Russia return to a GDP growth rate of 5.3 percent.

Ukraine, the second largest economy in the FSU, also reported positive economic growth in 2001—only its second year of positive GDP since the dissolution of the Soviet Union in 1989. Ukraine is a net importer of oil, and the high world oil prices did not benefit its economy. Instead, fiscal reform and strong growth in industrial output, construction activity, agriculture, and exports, along with fast-paced growth in domestic consumption and investment, helped to fuel Ukraine's economic growth. The improving economic outlook for Russia and the rest of the FSU suggests a more sustained period of growth for the region and is expected to result in energy demand growth for the region of 1.8 percent per year between 1999 and 2020, reaching 57 quadrillion Btu at the end of the forecast (Figure 5).

Worldwide, oil consumption rose by less than 100,000 barrels per day in 2001, divided evenly among the industrialized (mainly Western Europe) and developing (mainly Central and South America) nations. Demand is expected to begin to recover in 2002 as the world economies begin to recover from the slowdown in 2001, and

Figure 5. Percent Change in Energy Consumption and GDP in the Former Soviet Union



Sources: DRI-WEFA World Economic Outlook 2001, Third Quarter; Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001); and EIA, World Energy Projection System (2002).

global oil demand is projected to expand by about 600,000 barrels per day in 2002. The increases in worldwide oil use projected in the reference case would require an increment of almost 44 million barrels per day over current productive capacity. OPEC producers are expected to be the major beneficiaries of increased production requirements, but non-OPEC supply is expected to remain competitive, with major increments of supply coming from offshore resources, especially in the Caspian Basin, Latin America, and deepwater West Africa. Deepwater exploration and development initiatives are generally expected to be sustained worldwide, with the offshore Atlantic Basin emerging as a major future source of oil production in both Latin America and Africa.

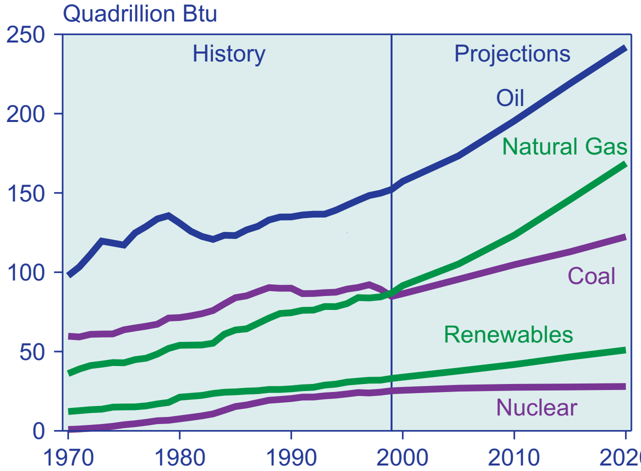
World Energy Consumption by Energy Source

Throughout the past several decades, oil has been the world's dominant source of primary energy consumption, and it is expected to remain in that position with a 40-percent share of total energy consumption over the 1999-2020 period (Figure 6). The oil share of the world energy pie does not increase in the forecast because countries in many parts of the world are expected to switch from oil to natural gas and other fuels, particularly for electricity generation. Its share of total energy consumption is expected to remain constant because of its predominance in the transportation sector, where energy use is projected to grow robustly over the next two decades. World oil consumption is projected to increase by 2.2 percent annually over the 21-year projection period, from 75 million barrels per day in 1999 to 119 million barrels per day in 2020.

Although the nations of the industrialized world continue to consume more of the world's petroleum products than do those of the developing world, the gap is projected to narrow considerably over the forecast period. In 1999, developing nations consumed 58 percent of the amount of oil consumed in the industrialized world, but by 2020 they are expected to consume almost 90 percent as much oil as the industrialized world. The increase in oil use in the industrialized world is expected to occur predominantly in the transportation sector, where there are presently few economically competitive alternatives to oil. In the developing world, oil demand is projected to grow in all end-use sectors. As the energy infrastructures of emerging economies improve, people are turning from traditional fuels like wood burning for heating and cooking to electricity, and additional petrochemical feedstocks are being used for industry.

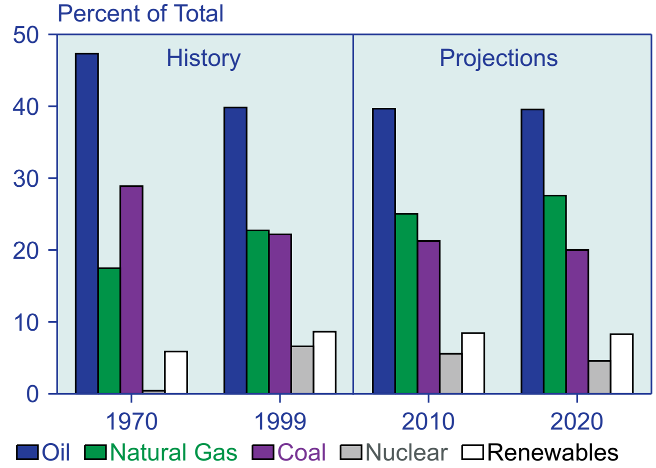
The fastest growing source of energy consumption in the *IEO2002* reference case is projected to be natural gas. Over the 1999-2020 forecast period, gas use is projected to nearly double in the reference case, reaching 162 trillion cubic feet in 2020. Natural gas use surpassed coal use (on a Btu basis) for the first time in 1999, and by 2020 it is expected to exceed coal use by 38 percent (Figure 7). The natural gas share of total energy consumption is projected to increase from 23 percent in 1999 to 28 percent in 2020, and natural gas is expected to account for the largest increment in electricity generation (increasing by 33 quadrillion Btu and accounting for 43 percent of the total increment in energy use for electricity generation). Much of the projected growth in natural gas consumption throughout the world is in response to rising demand for natural gas to fuel efficient new gas turbine

Figure 6. World Energy Consumption by Fuel Type, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 7. World Energy Consumption Shares by Fuel Type, 1970, 1999, 2010, and 2020



Sources: **1970 and 1999:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

power plants. Gas use is increasing for a number of additional reasons, including price, environmental concerns, fuel diversification and / or energy security issues, market deregulation (for both gas and electricity), and overall economic growth.

In the industrialized world, natural gas is expected to make a greater contribution to incremental energy consumption among the major fuels, increasingly becoming the choice for new power generation because of its environmental and economic advantages. In the developing countries, increments in gas use are expected to supply both power generation and industrial uses. The *IEO2002* reference case projects particularly robust growth in natural gas use in the developing world, averaging 5.3 percent per year between 1999 and 2020, reflecting the growing popularity of the fuel, as well as the expectation that the relatively immature gas markets of emerging countries will develop quickly over the coming years.

World coal use has been in a period of generally slow growth since the 1980s, and the trend is expected to continue through the projection period. The projected slow growth in coal consumption, averaging 1.7 percent per year through 2020, suggests that coal will account for a shrinking share of world energy consumption. In 1999, coal provided 22 percent of world primary energy consumption, down from 27 percent in 1985. In the *IEO2002* reference case, the coal share of total energy consumption is projected to fall to 20 percent by 2020. The expected decline in coal's share of energy use would be even greater were it not for large increases in energy use projected for developing Asia, where coal continues to dominate many fuel markets, especially in China and India. As very large countries in terms of both population and land mass, China and India are projected to account for 83 percent of the total expected increase in coal use worldwide (on a Btu basis).

Coal consumption is heavily concentrated in the electricity generation sector. Almost 65 percent of the world's coal use is for electricity generation, and power generation accounts for virtually all the projected growth in coal consumption worldwide. One exception is China, where coal continues to be the main fuel in a rapidly growing industrial sector, reflecting the country's abundant coal reserves and limited access to other sources of energy. Consumption of coking coal is projected to decline slightly in most regions of the world as a result of technological advances in steelmaking, increasing output from electric arc furnaces, and continuing replacement of steel by other materials in end-use applications.

Although past editions of this report have projected declines in nuclear electricity consumption, higher capacity utilization and fewer expected retirements of existing plants have resulted in a revision to the expectations for a decline in consumption. Extensions of operating licenses (or the equivalent) for nuclear power plants are expected to be requested and granted among the countries of the industrialized world. With more of the existing nuclear power plants expected to remain in operation, the projected decline in nuclear generation is slowed. In the *IEO2002* reference case, world nuclear capacity is projected to rise from 350 gigawatts in 2000 to 363 gigawatts in 2010 before falling to 359 gigawatts in 2020.

The highest growth in nuclear generation is projected for the developing world, where consumption of electricity from nuclear power is projected to increase by 4.7 percent per year between 1999 and 2020. In particular, developing Asia is expected to see the greatest expansion in new nuclear generating capacity. The nations of developing Asia account for half the reactors currently under construction worldwide, including eight in China, four in South Korea, two in India, and two in Taiwan.

Renewable energy use is expected to increase by 53 percent between 1999 and 2020, but its current 9-percent share of total energy consumption is projected to drop slightly to 8 percent by 2020. Over the forecast horizon, growth in renewable energy resources is expected to continue to be constrained by relatively moderate fossil fuel prices. Renewable energy consumption is expected to be driven by new, large-scale hydroelectric projects, particularly in China, India, Malaysia, and other developing Asian countries. In 2001, construction on megahydro projects like China's 18,200-megawatt Three Gorges Dam and Malaysia's 2,400-megawatt Bakun continued amidst criticism of their environmental impacts and concerns about the welfare of the people being relocated to accommodate the projects.

The world's use of electricity is projected to increase by two-thirds over the forecast horizon, from 13 trillion kilowatthours in 1999 to 22 trillion kilowatthours in 2020. The strongest growth rates in electricity consumption are projected for developing Asia, where electricity consumption is expected to grow by 4.5 percent per year as robust economic growth increases the demand for electricity to run newly purchased air conditioners, refrigerators, stoves, space heaters, and water heaters. In the industrialized world, electricity consumption is expected to grow at a more modest pace. Slower population and economic growth, along with the market saturation of certain electronic appliances (such as air conditioners) and efficiency gains from electrical appliances help to explain the expected slower growth of electricity use in the industrialized nations, although growing computer usage and the introduction of new electronic devices could moderate that trend somewhat in the future.

There have been two important developments in the electricity sector in recent years that may affect the way the industry works in the future. The first is the increasing role of foreign direct investment in the developing regions of the world. Greater access to foreign investment in the electricity sector has allowed developing nations to construct the infrastructure needed for substantial increases in access to electricity, a particular problem for many developing nations. A second important component of the electric industry's evolution over the past several years is electricity reform. Many developing countries have implemented reforms to the rules governing electricity generation and distribution in an effort to secure the foreign direct investment they need to modernize and improve the electricity infrastructure. In industrialized countries, many nations have undertaken electricity reforms to introduce greater competition in domestic markets in an effort to reduce the costs of electricity to consumers.

Outlook for Transportation Energy Use

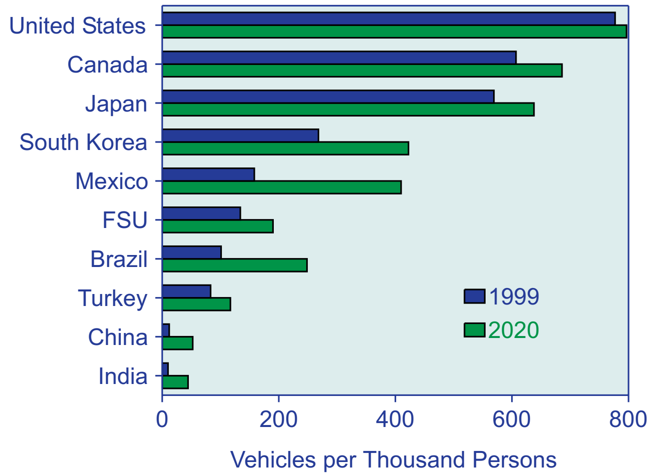
The past year saw a reversal of the high prices and tight markets that characterized the energy industry in 2000. Transportation demand growth in 2001 is likely to be the lowest in several years, with slowing economic growth moderating growth in world oil demand even before the September 11 terrorist attacks on the United States. Despite the recent pressure on transportation fuels from oil prices that hit 10-year highs in 2000, transportation energy use is expected to continue robust growth over the next two decades, especially in the developing world, where relatively immature transportation infrastructures are expected to grow rapidly as national and regional economies expand. In the *IEO2002* reference case, energy use for transportation is projected to increase by 3.8 percent per year in the developing world, compared with average annual increases of 1.7 percent for the industrialized countries, where transportation systems are largely established and motorization levels (per capita vehicle ownership) are, in many nations, expected to reach saturation levels over the 21-year forecast horizon.

In urban centers of the developing world, car ownership is often seen as one of the first symbols of emerging prosperity. Per capita motorization in much of the developing world is projected to more than double between 1999 and 2020, although population growth is expected to keep motorization levels low relative to those in the industrialized world. For example, the U.S. per capita motorization level in 2020 is projected at 797 vehicles per thousand persons, but in China—where motorization is expected to grow fivefold over the forecast horizon—the projected motorization level in 2020 is only 52 vehicles per thousand persons (Figure 8).

Carbon Dioxide Emissions

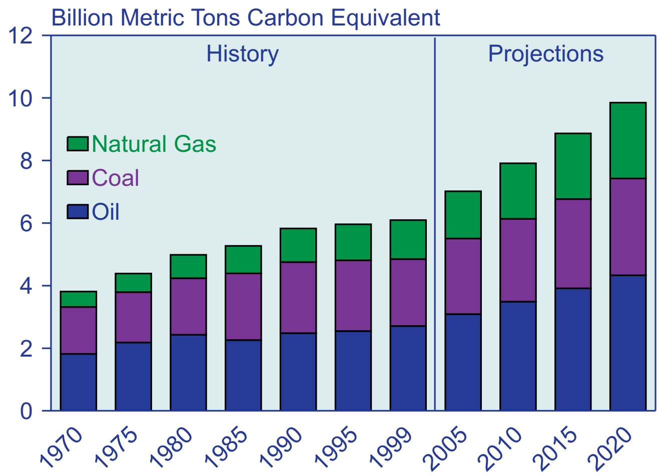
Because estimates indicate that approximately 80 percent of all human-caused carbon dioxide emissions currently come from fossil fuel combustion, world energy use has emerged at the center of the climate change debate. In the *IEO2002* reference case, world carbon dioxide emissions are projected to rise from 6.1 billion metric tons carbon equivalent in 1999 to 7.9 billion metric tons per year in 2010 and to 9.9 billion metric tons in 2020 (Figure 9). Much of the projected increase in carbon dioxide emissions is expected to occur in the developing world, where emerging economies are expected to produce the largest increases in energy consumption. Developing countries alone account for 77 percent of the projected increment in carbon dioxide emissions between 1990 and 2010 and 72 percent between 1990 and 2020. Continued heavy reliance on coal and other fossil

Figure 8. Motorization Levels in Selected Countries, 1999 and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

Figure 9. World Carbon Dioxide Emissions by Fossil Fuel, 1970-2020



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

fuels, as projected for the developing countries, would ensure that even if the industrialized world undertook efforts to reduce carbon dioxide emissions, worldwide carbon dioxide emissions would still grow substantially over the forecast horizon.

Energy Intensity

The *IEO2002* projections, like all forecasts, are accompanied by a measure of uncertainty. One way to quantify the uncertainty is to consider the relationship between energy consumption and growth in gross domestic product (that is, energy intensity) over time. In the industrialized countries, history shows the link between energy consumption and economic growth to be a relatively weak one, with growth in energy demand lagging behind economic growth. In the developing countries, the two have been more closely correlated, with energy demand growing in parallel with economic expansion.

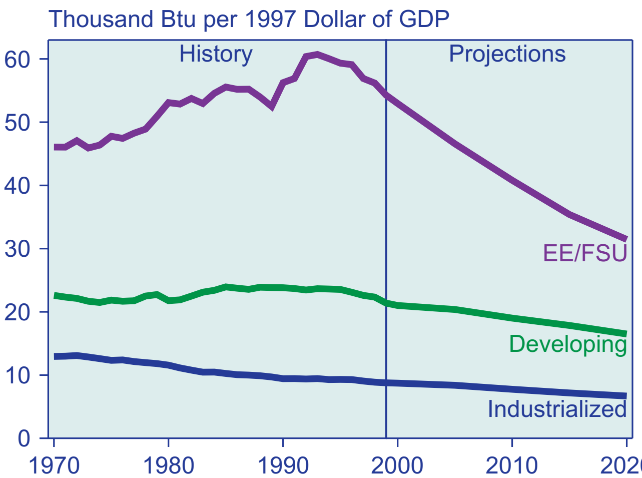
In the *IEO2002* forecast, energy intensity in the industrialized countries is expected to improve (decrease) by 1.3 percent per year between 1999 and 2020, about the same rate of improvement observed in the region between 1970 and 1999. Energy intensity is also projected to improve in the developing countries—by 1.2 percent per year—as their economies begin to behave more like those of the industrialized countries as a result of improving standards of living that accompany the projected economic expansion (Figure 10). For more than three decades, the EE/FSU has maintained a much higher level of energy intensity than either the industrialized or developing countries. Over the forecast horizon, energy intensity is expected to improve in the EE/FSU region in concert with expected recovery from the economic and social declines of the early 1990s; however, it is still expected to be twice as high as in the developing world and five times as high as in the industrialized world.

Carbon Intensity

Carbon intensity—the amount of carbon dioxide emitted per dollar of GDP—is also projected to improve throughout the world over the next two decades (Figure 11). The most rapid improvements are, for the most part, projected for the transitional economies of the EE/FSU. In the FSU, economic recovery from the upheaval of the 1990s is expected to continue throughout the forecast. The FSU nations are also expected to replace old and inefficient capital stock and increasingly use less carbon-intensive natural gas for electricity generation and other end uses in place of more carbon-intensive oil and coal.

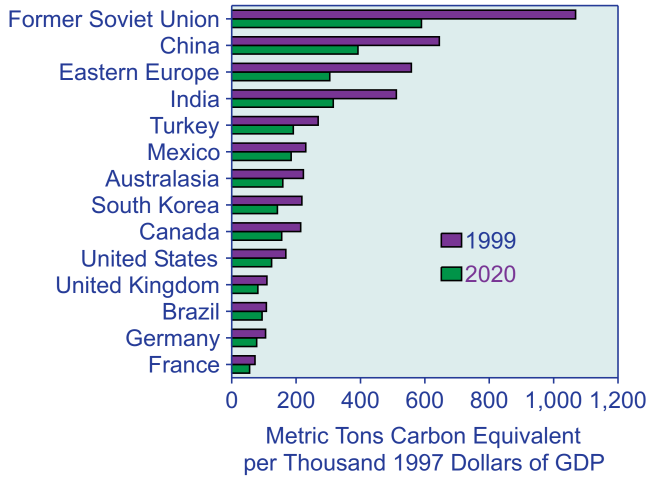
In developing Asia, China and India are also expected to see fairly rapid improvements in carbon intensity over the projection period, primarily as a result of rapid economic growth rather than a switch to less carbon-intensive fuels. Both China and India are expected to continue their heavy dependence on fossil fuels, especially coal, in the *IEO2002* reference case forecast, but their combined annual GDP growth is projected to average 6.6 percent, compared with an expected 4.4-percent annual rate of increase in fossil fuel use from 1999 to 2020.

Figure 10. World Energy Intensity by Region, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 11. Carbon Intensity in Selected Countries and Regions, 1999 and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).